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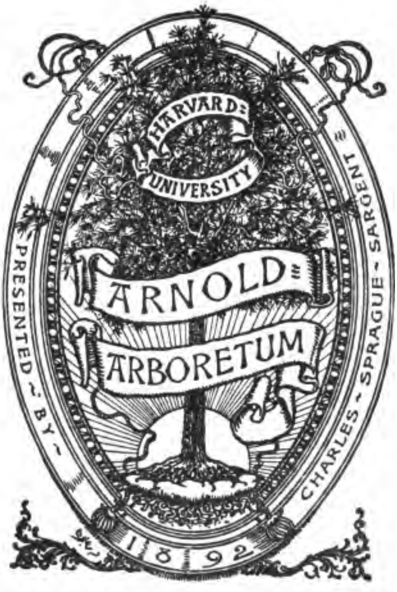

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FARMERS' BULLETIN No. 173.

A PRIMER OF FORESTRY.

[Pt. 1]

BY

GIFFORD PINCHOT,
FORESTER.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Forestry,
Washington, D. C., May 25, 1903.

Sir: Nearly four years ago the Department issued as Bulletin No. 24, Division of Forestry, a publication entitled A Primer of Forestry. The demand for this bulletin has been large and continuous, and notwithstanding the fact that two editions, aggregating 45,000 copies, have been issued, the supply is now exhausted. Owing to the expensive character of this bulletin in its original form, I have thought it advisable to recommend its republication in the popular and more economical Farmers' Bulletin series. With this end in view, I have slightly revised the text, and a large number of the illustrations have been engraved in order to adapt them for use as text figures. It is believed that in its new form the bulletin will be even more useful than heretofore because of the possibility of giving it a very much wider distribution.

Gifford Pinchot, *Forester.*

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

Page.
The life of a tree ... 5
The parts of a tree ... 6
The food of a tree ... 7
The composition of wood ... 8
How the tree breathes ... 8
Transpiration ... 9
The growth of a tree ... 9
The structure of wood ... 11
Annual rings ... 13
Heartwood and sapwood ... 13
Trees in the forest ... 14
The various requirements of trees ... 15
Requirements of trees for heat and moisture ... 16
Requirements of trees for light ... 17
Tolerance and intolerance ... 18
The rate of growth ... 19
The reproductive power of trees ... 20
Pure and mixed forest ... 21
Reproduction by sprouts ... 23
The life of a forest ... 23
A community of trees ... 23
The life of a forest crop ... 25
The seven ages of a tree ... 26
How the crop begins ... 26
The forest cover established ... 27
The beginning of the struggle ... 27
Growth in height ... 28
The struggle continued ... 29
Natural pruning ... 29
The culmination of growth ... 31
The end of the struggle ... 31
Death from weakness and decay ... 32
Destructive lumbering ... 34
Conservative lumbering ... 34
Enemies of the forest ... 35
Man and nature in the forest ... 35
Grazing in the forest ... 35
Grazing and fire ... 36
Trampling ... 37
Browsing ... 37
Forest insects ... 38
Forest fungi ... 38
Wind in the forest ... 38
Snow in the forest ... 40
Forest fires ... 41
Historic forest fires ... 42
Means of defense ... 43
Surface fires ... 44
Ground fires ... 45
Back firing ... 46
Fire lines ... 47

ILLUSTRATIONS.

Page.
Fig. 1. Roots, stem, and crown of a young Shellbark Hickory 5
2. Upturned skeleton roots of a Red Fir 6
3. Trunks of two Red Firs 7
4. Stem and crown of a Longleaf Pine 7
5. Cross section of wood and bark of the Western Yellow Pine 9
6. Yearly growth of a branch of Horse Chestnut 10
7. Perpendicular cut of wood and bark of the Western Yellow Pine 10
8. Outer surface of bark of the Western Yellow Pine 11
9. Wood of a spruce greatly magnified 12
10. Wood of Western Hemlock 13
11. Annual rings 13
12. A section of the common Staghorn Sumach 14
13. A forest of palms in southern Florida 15
14. The Black Hemlock in its home 16
15. Young oaks starting under an old forest of pines 19
16. Winged seeds 20
17. Chestnut sprouts from the stump 22
18. Forest trees standing too far apart to help each other 24
19. A White Pine seedling, showing the slender roots 25
20. Young White Pine seedlings whose lower branches have just begun to interfere 27
21. Imperfect natural pruning of a White Pine that stood too much alone in early youth 30
22. Diagram to show why a sharply conical crown receives more light than a flat one 32
23. Young growth under old trees 33
24. Destructive lumbering in the Coast Redwood Belt 34
25. Band of sheep in a forest reserve 36
26. A windfall in the Olympic Forest Reserve 39
27. A young spruce loaded with snow 40
28. The rotting stubs of fire-killed veterans of Red Fir 41
29. A surface fire burning slowly against the wind 44
30. The effect of repeated fires 45
31. The result of recurring fires 46
32. Setting a back fire on the windward side of a road 46
33. A fire line along a railroad 47

A PRIMER OF FORESTRY.

THE LIFE OF A TREE.

The object of forestry is to discover and apply the principles according to which forests are best managed. It is distinct from arboriculture, which deals with individual trees. Forestry has to do with single trees only as they stand together on some large area whose principal crop is trees, and which therefore forms part of a forest. The forest is the most highly organized portion of the vegetable world. It takes its importance less from the individual trees which help to form it than from the qualities which belong to it as a whole. Although it is composed of trees, the forest is far more than a collection of trees standing in one place. It has a population of animals and plants peculiar to itself, a soil largely of its own making, and a climate different in many ways from that of the open country. Its influence upon the streams alone makes farming possible in many regions, and everywhere it tends to prevent floods and drought. It supplies fuel, one of the first necessaries of life, and lumber, the raw material, without which cities, railroads, and all the great achievements of material progress would have been either long delayed or wholly impossible. The forest is as beautiful as it is useful. The old fairy tales which spoke of it as a terrible place are wrong. No one can really know the forest without feeling the gentle influence of one of the kindliest and

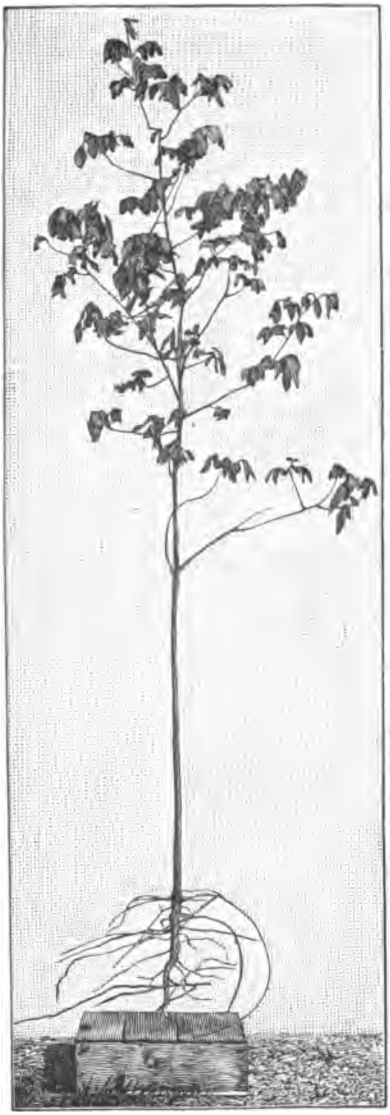

FIG. 1.—Roots, stem, and crown of a young Shellbark Hickory.

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THE PARTS OF A TREE

[illegible] first be [illegible] a woody [illegible] (Fig. 1). [illegible] into the [illegible]

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[illegible] the soil is not [illegible] the surface: they [illegible] and certain min- [illegible] the trunk or [illegible] with mineral [illegible] Fig. 4), with its [illegible] taken up by [illegible] made ready to assist [illegible]

[illegible] tree than its other [illegible] germination of the tree and the digestion of its food take place in the crown. For this reason, and because we can control its shape and size more easily and directly than that of the roots or trunk, the crown is of special interest to the forester. It is almost exclusively with the crowns that he has to deal in tending a crop of trees and preparing the way for the succeeding generation. As they stand together in the forest, the crowns of the trees form a broken shelter, which is usually spoken of as the leaf canopy, but which may better be called the cover.

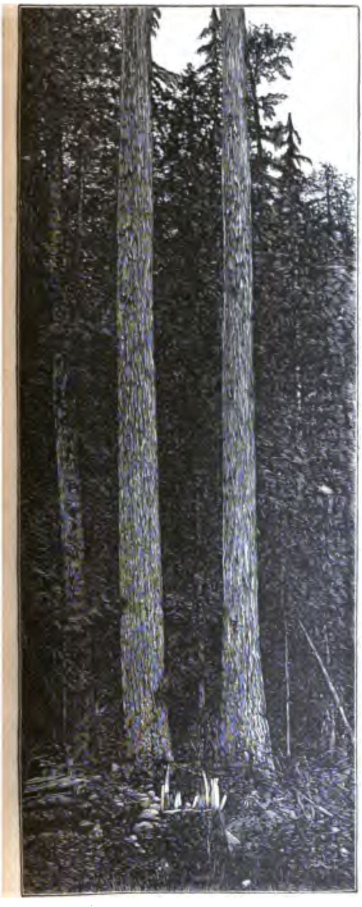

FIG. 3.—Trunks of two Red Firs of great size. Olympic Forest Reserve, Washington.

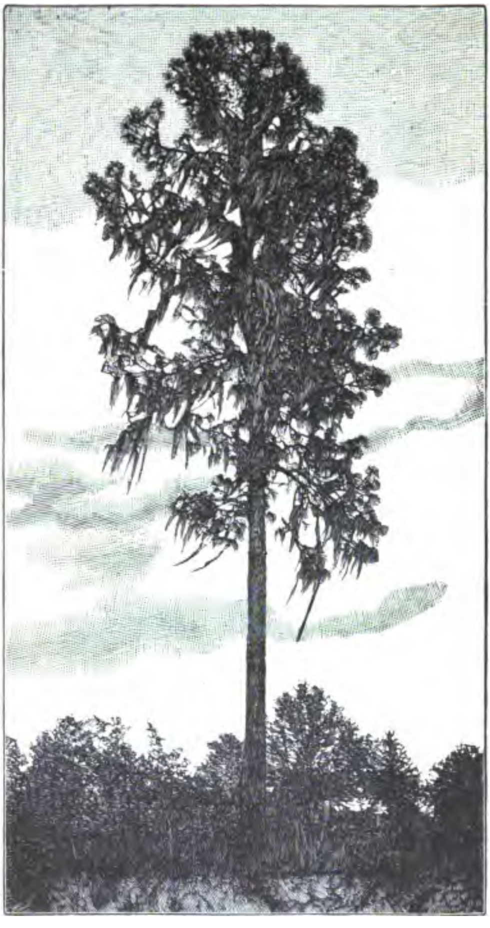

FIG. 4.—Stem and crown of a Longleaf Pine, the latter covered with moss swaying in the wind.

THE FOOD OF A TREE.

The materials upon which a tree feeds are derived from the soil and the air. The minute root hairs which spring from the rootlets take up water from the ground, and with it various substances which it [illegible] in solution. These are the earthy constituents of the tree, which reappear in the form of ashes when any part of it is burned. The water which contains these materials goes straight from the roots to the leaves, in which a most important process in the feeding of the tree takes place. This process is the assimilation or taking up and making into food of carbonic-acid gas from the air. It goes on only in the presence of light and heat and through the action of chlorophyll, a substance from which the leaves and the young bark get their green color.

Plants containing chlorophyll are the chief means by which mineral materials are changed into food, so that nearly all plant and animal life depends upon them. Plant cells which contain chlorophyll break up the carbonic-acid gas with which they come in contact, retain the carbon, one of its elements, and send back the other, oxygen, into the air. Then, still under the influence of the sunlight, they combine the carbon with the oxygen and hydrogen of the water from the roots into new chemical compounds, in which nitrogen and the earthy constituents [illegible] are also present; that is to say, the food materials which reach the tree through the roots and leaves are first digested in the leaves somewhat as food is digested in the human body, and are then sent to all living parts of the roots, stem, and crown, where they pass through another process of digestion, and are then either used at once in growth or stored away until the proper moment arrives. This is the general rule, but it is believed that in some cases food taken up by the roots can be used without first being digested in the leaves.

THE COMPOSITION OF WOOD.

Wood is made up chiefly of carbon, oxygen, and hydrogen. When perfectly dry, about half its weight is carbon, and half oxygen and hydrogen, in almost the same proportion as in water. It contains also about 1 part in 100, by weight, of earthy constituents, and nitrogen to the same amount. When wood is burned, all these materials disappear into the air except the earthy constituents. Now, the nitrogen and water taken up by the roots were originally in the air before they reached the ground. It is true, therefore, that when wood is burned those parts of it which came from the air go back into it in the form of gas, while those which came from the soil remain behind in the form of ashes.

HOW THE TREE BREATHES.

Besides giving out oxygen in assimilation, trees also take in oxygen from the air through their leaves, and through the minute openings in the bark called lenticels, such as the oblong raised spots or marks on the young branches of birch and cherry and many other trees. All plants, like all animals, breathe; and plants, like animals, breathe in oxygen and breathe out carbonic acid gas. This process of respiration or the breathing of the tree goes on both day and night, but it is far less active than assimilation, which takes place only in the light. Consequently more carbonic-acid gas is taken into the tree than is given out, and the surplus carbon remains to be used in growing.

TRANSPIRATION.

The leaves give out not only the oxygen derived from the decomposition of carbonic-acid gas taken from the air and carbonic-acid gas produced in breathing, but also great quantities of water vapor. The amount of water taken up by the roots is very much larger than is required to be combined with carbon and the earthy constituents in the leaves. In order that fresh supplies of earthy constituents in solution may reach the leaves rapidly the water already in them must be got out of the way. This is effected by transpiration, which is the evaporation of water from all parts of the tree above ground, but principally from the leaves. Even where the bark is very thick, as on the trunks of old oaks and chestnuts, transpiration goes on through the lenticels in the bottoms of the deep cracks (fig. 5). It sometimes happens, especially in spring before the leaves come out, that transpiration can not get rid of the water from the roots as fast as it rises, and that it falls in drops from the buds, or later on even from the leaves themselves.

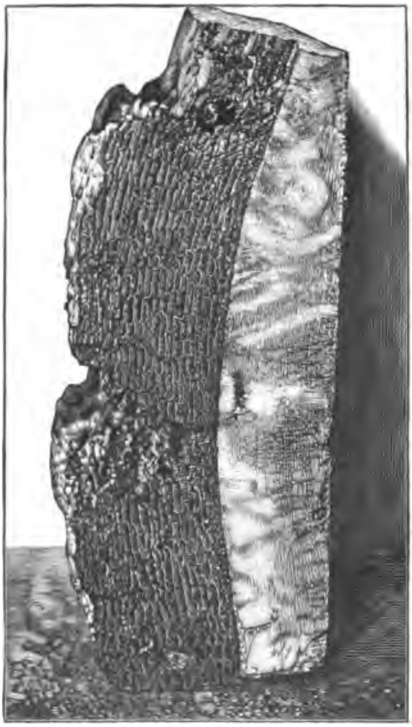

FIG. 5.—Cross section of wood and bark of the Western Yellow Pine, showing two of the deep cracks in the bark, at the bottom of which lenticels are placed.

THE GROWTH OF A TREE.

The addition of new material in the way described in the preceding pages is the foundation of growth. Except in the buds, leaves, fruit, and the twigs less than a year old, this material is deposited in a thin coat over the whole tree between the wood and the bark. The new twigs grow in length by a kind of stretching, but only during the first year. Thus it is only by means of these youngest twigs that a tree increases in height and in spread of branches. After the first year their length is fixed, younger twigs stretch out from the buds,

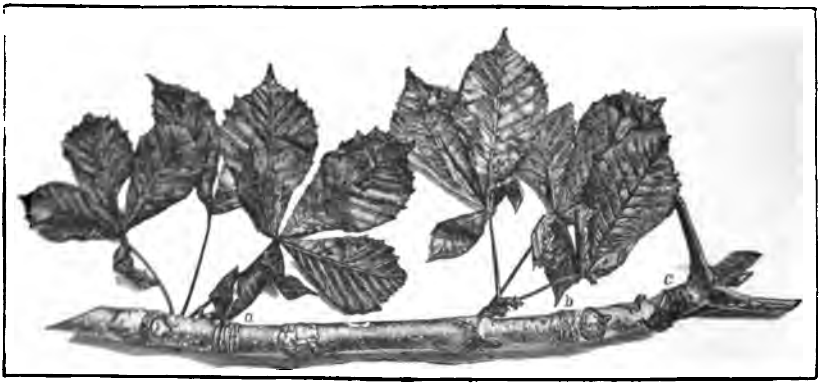

FIG. 6.—Yearly growth of a branch of Horse Chestnut. The bands of wrinkles mark the divisions between the growths of four successive years. The distance between these bands would never have been greater than it was when the branch was cut.

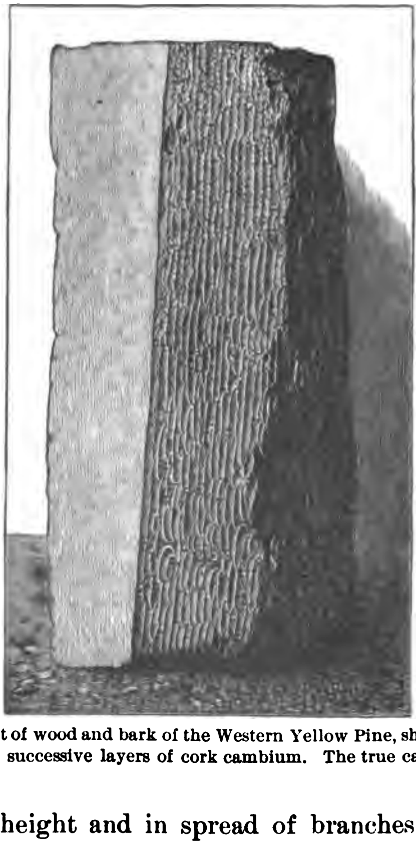

FIG. 7.—Perpendicular cut of wood and bark of the Western Yellow Pine, showing the division of the bark into scales by the successive layers of cork cambium. The true cambium is between wood and bark.

and the older ones grow henceforth only in thickness (fig. 6). The fresh coat of new material mentioned above covers them year by year. There are two layers in this coat, separated by a third one of tender forming tissues called the cambium, in which the actual making of the new substance goes on. The inner side of the cambium layer forms new wood, the outer side new bark. Besides the true cambium, which forms both wood and bark, there is another cambium which makes the corky outer bark and nothing else (figs. 7 and 8). This cork cambium may encircle the whole tree, like the true cambium, as in the Red Cedar, or it may form little separate films in the bark, but in either case it dies from time to time, and is re-formed nearer the wood.

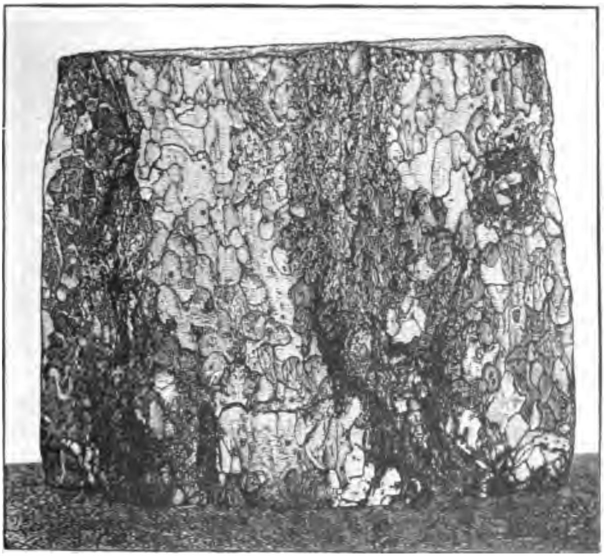

FIG. 8.—Outer surface of bark of the Western Yellow Pine, showing the scales made by the successive layers of cork cambium.

THE STRUCTURE OF WOOD.

Wood is chiefly made up of very small tubes or cells (fig. 9) of various kinds, which have special uses in the life of the tree. Some conduct water from the roots to the crown, some store away digested food, and others merely strengthen the structure of the wood and hold it together. The wood of cone-bearing or coniferous trees (like the pines and spruces) has but few kinds of cells, while that of the broadleaf trees (such as oaks and maples) is much less simple. But in each case some of the cells have thick walls and small openings, and others wide openings and very thin walls. In climates which have regularly one season of growth and one of rest, like our own, the cells of the layer of new wood formed each year at the inner surface of the cambium are arranged in a definite way. When growth begins in the spring, and the fresh twigs and leaves put out, there is a great demand for water in the crown to supply these moist green new parts of the tree. Water rises in most trees through the newer layers of the wood, and especially through the last ring. Consequently, at first the tree makes thin-walled cells with wide openings, through which water can rise rapidly to the ends of the branches. Later on, when the demand for water is not so great, and there is plenty of digested food to supply building material, the cells formed are narrow and thick-walled. Thus the summer wood in each year's growth is heavier, stronger, and darker in color than the spring wood. In the wood of many broadleaf trees, such as oak and chestnut, the spring wood is also marked by a band of open tubes of larger size called ducts. In others, such as maple and beech, these ducts are scattered through the whole season's growth, and in all conifers, as for example the pines and cedars, they are entirely wanting. But the differences in hardness and color between the growth of spring and summer are still present. It is sometimes possible to see the line which separates the growth of two seasons in the bark, as in the case of common cork, which is the outer bark of the Cork Oak, a native of southern Europe.

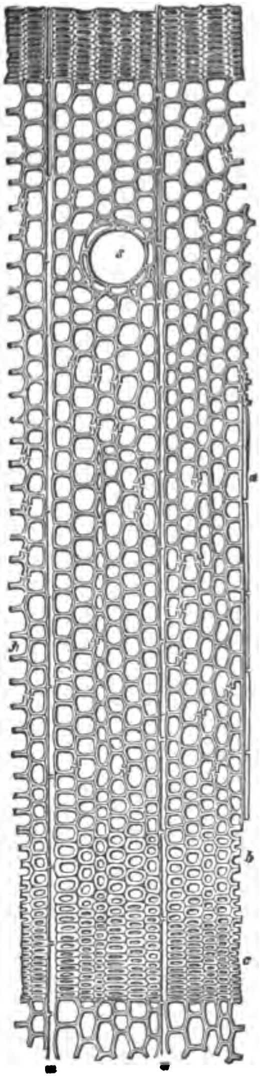

FIG. 9.—Wood of a spruce, greatly magnified.

If the trunk or branch of an oak tree is cut smoothly across, thin whitish lines may be seen running from within outward (fig. 10, block at the right). Some of these lines begin in the center of the tree and others in each one of the annual rings. These are the medullary rays, which make the silver grain in quartered oak and other woods. They exist in all kinds of trees, but in many—as, for example, in the Chestnut and in most conifers—they are so fine as hardly to be seen with the naked eye. Seasoning cracks which run across the rings of growth always follow the lines of these rays, while others most often follow along some nual ring.

ANNUAL RINGS.

It is correct to speak of these rings of growth as "annual rings," for as long as the tree is growing healthily a ring is formed each year

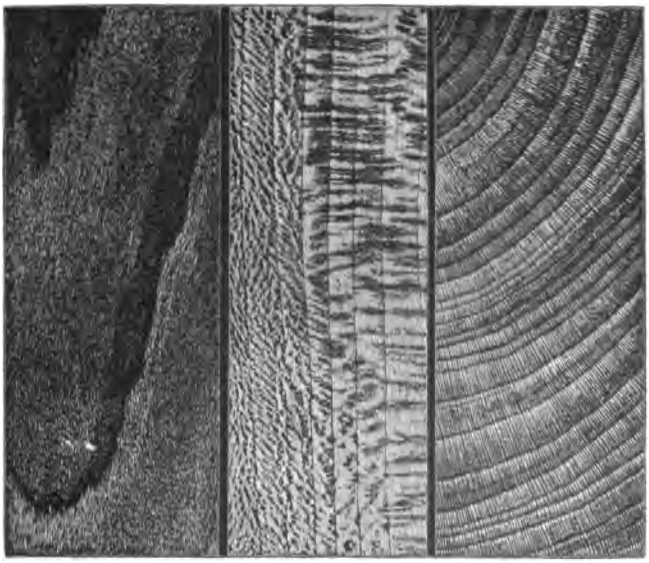

FIG. 10.—Wood of Western Hemlock.

(figs. 10, 11). It is true that two false rings may appear in one year, but they are generally so much thinner than the rings on each side that it is not hard to detect them. Very often they do not extend entirely around the tree, as a true ring always does if the tree is sound. Whenever the growth of the tree is interrupted and begins again during the same season, such a false ring is formed. This happens when the foliage is destroyed by caterpillars and grows again in the same season, or when a very severe drought in early summer stops growth for a time, after late frosts, and in similar cases.

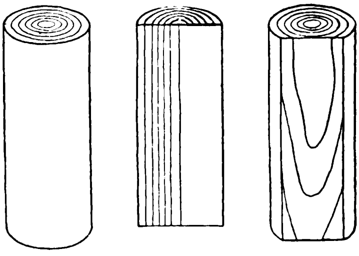

FIG. 11.—Annual rings.

HEARTWOOD AND SAPWOOD.

An annual layer once formed does not change in size or place during the healthy life of the tree, except that it is covered in time by other, younger layers. A nail driven into a tree 6 feet from the ground will still be at the same height after it is buried under 20 or 50 or 100 layers of annual growth. But in most trees, like the oaks and pines, the wood becomes darker in color and harder after it has been in the tree for some years. The openings of its cells become choked so th the sap can no longer run through them. From living sapwood, i which growth is going on, it becomes heartwood, which is dead because it has nothing to do with growth (fig. 12). It is simply a stron framework which helps to support the living parts of the tree. Thi is why hollow trees may flourish and bear fruit. When the tree i cut down, the sapwood rots more easily than the heartwood, becaus it takes up water readily and contains plant food, which decays ver fast. Not all trees have heartwood and in many the difference in colo between it and the sapwood is ver slight. Since water from the roo rises only in the sapwood, it is ea to kill trees with heartwood b girdling them, provided all the sapwood is cut through. But in those which have no heartwood the tube of the older layers of wood can st convey water to the crown, a when such trees are girdled it often several years before they d

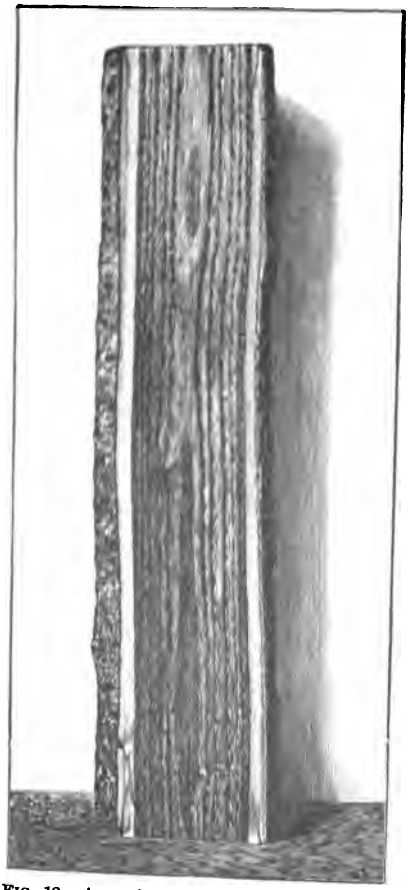

Fig. 12.—A section of the common Staghorn Sumach, showing the darkened heartwood, the white sapwood, and the inner and outer bark. Milford, Pa.

A great many theories have b proposed to account for the rise water into the tops of tall tre some of which, as in the big tre of California, may be over 300 fe from the ground. But none of th theories is quite satisfactory, and must be admitted that we do not y know how the trees supply the lofty crowns with the water whi keeps them alive.

TREES IN THE FOREST.

The nature of a tree, as shown b its behavior in the forest, is calle its silvicultural character. It i made up of all those qualities up which the species as a whole, and every individual tree, depend in thei struggle for existence. The regions in which a tree will live, and th places where it will flourish best; the trees it will grow with, and thos which it kills or is killed by; its abundance or scarcity; its size an rate of growth—all these things are decided by the inborn qualitie -- silvicultural character, of each particular kind of tree.

15

THE VARIOUS REQUIREMENTS OF TREES.

Different species of trees, like different races of men, have special requirements for the things upon which their life depends. Some races, like the Eskimos, live only in cold regions. Others, like the South Sea Islanders, must have a very warm climate to be comfortable, and are short-lived in any other (fig. 13). So it is with trees, except that their different needs are even more varied and distinct. Some of them, like the willows, birches, and spruces of northern Canada, stand on the boundary of tree growth within the Arctic Circle. Other species grow only in tropical lands, and can not resist even the lightest frost. It is always the highest and lowest temperature, rather than the average, which decides where a tree will or will not grow. Thus the average temperature of an island where it never freezes may be only 60°, while another place, with an average of 70°, may have occasional frosts. Trees which could not live at all in the latter on account of the frost might flourish in the lower average warmth of the former.

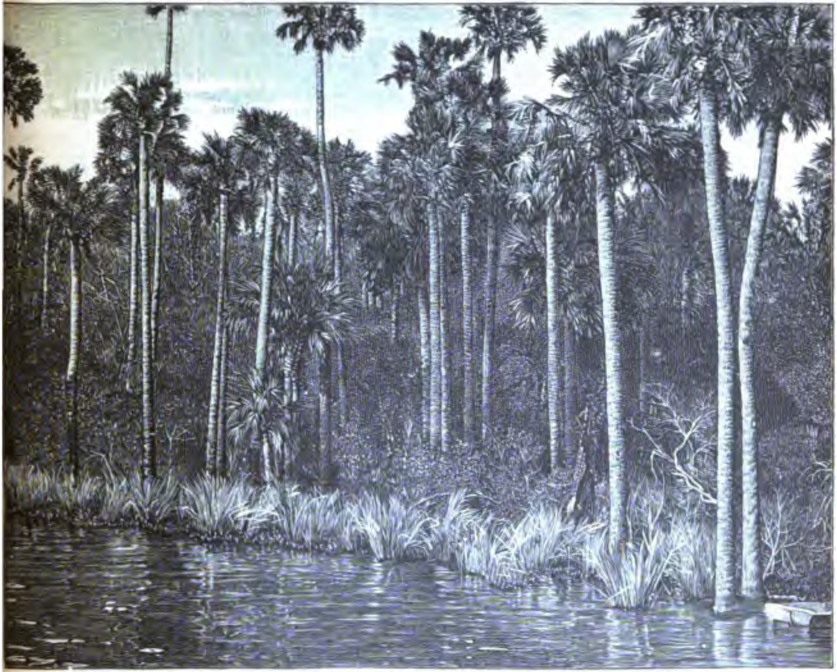

FIG. 13.—A forest of palms in southern Florida.

In this way the influence of heat and cold on trees has a great deal to do with their distribution over the surface of the whole earth. Their distribution within shorter distances also often depends largely upon it. In the United States, for example, the Live Oak does not grow in Maine nor the Canoe Birch in Florida. Even the opposite sides of the same hill may be covered with two different species, because one of them resists the late and early frosts and the fierce midday heat of summer, while the other requires the coolness and moisture of the northern slope (fig. 14). On the eastern slopes, where the sun strikes early in the day, frosts in the spring and fall are far more apt to kill the young trees or the blossoms and twigs of older ones than on those which face to the west and north, where growth begins later in the spring, and where rapid thawing, which does more harm than the freezing itself, is less likely to take place.

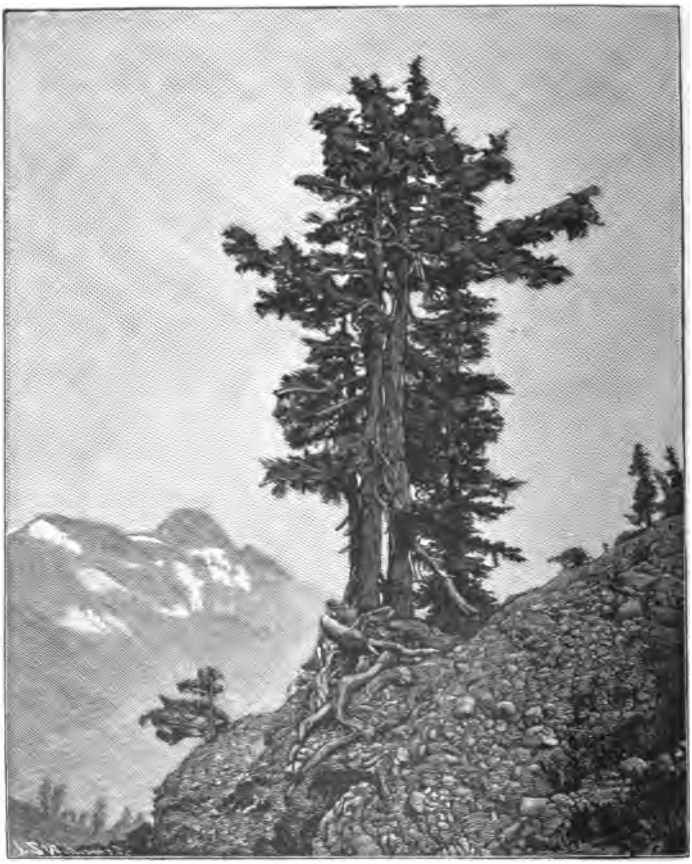

FIG. 14. The Black Hemlock in its home, Cascade Mountains of Washington.

REQUIREMENTS OF TREES FOR HEAT AND MOISTURE.

Heat and moisture act together upon trees in such a way that it is sometimes hard to distinguish their effects. A dry country or a dry slope is apt to be hot as well, while a cool northern slope is almost always moister than one turned toward the south. Still the results of the demand of trees for water can usually be distinguished from the results of their need of warmth, and it is found that moisture has almost as great an influence on the distribution of trees over the earth as heat itself. Indeed, within any given region it is apt to be much more conspicuous, and the smaller the region the more noticeable often is its effect, because the contrast is more striking. Thus it is frequently easy to see the difference between the trees in a swamp and those on a dry hillside nearby, when it would be far less easy to distinguish the general character of the forest which includes both swamp and hillside from that of another forest at a distance. In many instances the demand for water controls distribution altogether. For this reason the forests on the opposite sides of mountain ranges are often composed of entirely different trees. On the west slope of the Sierra Nevada of California, for example, where there is plenty of moisture, there is also one of the most beautiful of all forests. The east slope, on the contrary, has comparatively few trees, because its rainfall is very slight, and those which do grow there are small and stunted in comparison with the giants on the west. Again, certain trees, like the Bald Cypress and the River Birch, are commonly found only in very moist land; others, like the mesquites and the Pinyon or Nut Pine, only on the driest soils; while still others, like the Red Cedar and the Red Fir, seem to adapt themselves to almost any degree of moisture, and are found on both very wet and very dry soils. In this way the different demands for moisture often separate the kinds of trees which grow in the bottom of a valley from those along its slopes, or even those in the gullies of hillsides from those on the rolling land between. A mound not more than a foot above the level of a swamp is often covered with trees entirely different from those of the wetter lower land about it.

Such matters as these have far more to do with the places in which different trees grow than the chemical composition of the soil. But its mechanical nature—that is, whether it is stiff or loose, fine or coarse in grain, deep or shallow—is very important, because it is directly connected with heat and moisture and the life of the roots in the soil.

REQUIREMENTS OF TREES FOR LIGHT.

The relations of trees to heat and moisture are thus largely responsible for their distribution upon the great divisions of the earth's surface, such as continents and mountain ranges, as well as over the smaller rises and depressions of every region where trees grow. But while heat and moisture decide where the different kinds of trees can grow, their influence has comparatively little to do with the struggles of individuals or species against each other for the actual possession of the ground. The outcome of these struggles depends less on heat and moisture than on the possession of certain qualities, among which is the ability to bear shade. With regard to this power trees are roughly divided into two classes, often called shade-bearing and light-demanding, following the German, but better named tolerant and intolerant of shade. Tolerant trees are those which flourish under more or less heavy shade in early youth; intolerant trees are those which demand a comparatively slight cover, or even unrestricted light. Later in life all trees require much more light than at first, and usually those of both classes can live to old age only when they are altogether unshaded from above. But there is always this difference between them: The leaves of tolerant trees will bear more shade. Consequently the leaves on the lower and inner parts of the crown are more vigorous, plentiful, and persistent than is the case with intolerant trees. Thus the crown of a tolerant tree in the forest is usually denser and longer than that of one which bears less shade. It is usually true that the seedlings of trees with dense crowns are able to flourish under cover, while those of light-crowned trees are intolerant. This rough general rule is often of use in the study of forests in a new country, or of trees whose silvicultural character is not known.

TOLERANCE AND INTOLERANCE.

The tolerance or intolerance of trees is one of their most important silvicultural characters. Frequently it is the first thing a forester seeks to learn about them, because what he can safely undertake in the woods depends so largely upon it. Thus tolerant trees will often grow vigorously under the shade of light-crowned trees (fig. 15) above them, while if the positions were reversed the latter would speedily die. The proportion of different kinds of trees in a forest often depends on their tolerance. Thus hemlock sometimes replaces White Pine in Pennsylvania, because it can grow beneath the pine, and so be ready to fill the opening whenever a pine dies. But the pine can not grow under the hemlock, and can only take possession of the ground when a fire or a windfall makes an opening where it can have plenty of light. Some trees after being overshaded can never recover their vigor when at last they are set free. Others do recover and grow vigorously even after many years of starving under heavy shade. The Red Spruce in the Adirondacks has a wonderful power of this kind, and makes a fine tree after spending the first fifty or even one hundred years of its life in reaching a diameter of two inches.

The relation of a tree to light changes not only with its age, but also with the place where it is growing, and with its health. An intolerant tree will stand more cover where the light is intense than in a cloudy northern region, and more if it has plenty of water than with a scanty supply. Vigorous seedlings will get along with less light than sickly ones. Seedlings of the same species will prosper under heavier shade if they have always grown under cover than if they have had plenty of light at first and have been deprived of it afterwards.

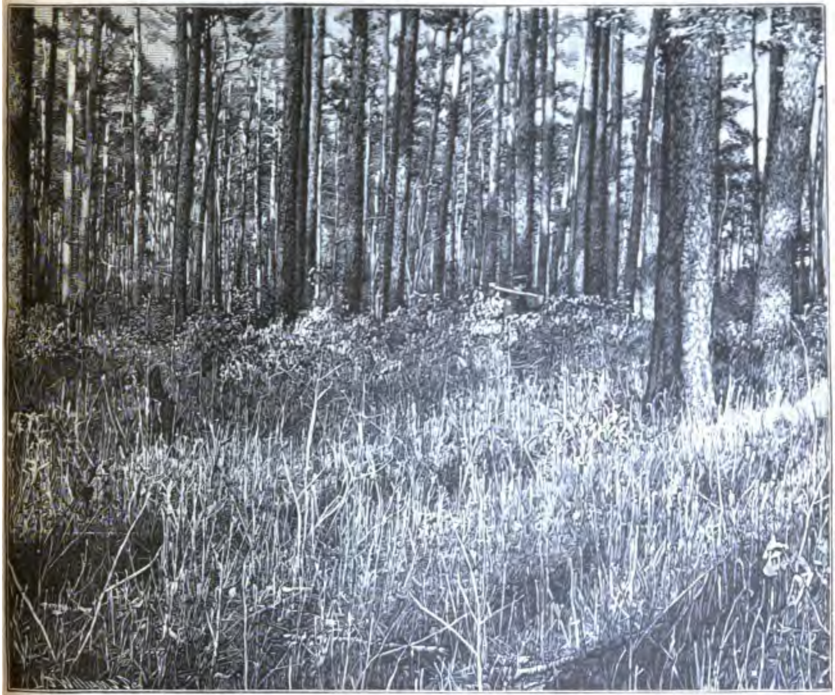

FIG. 15.—Young oaks starting under an old forest of pines. Eastern North Carolina.

THE RATE OF GROWTH.

The rate of growth of different trees often decides which one will survive in the forest. For example, if two intolerant kinds of trees should start together on a burned area or an old field, that one which grows faster in height will overtop the other and destroy it in the end by cutting off the light. Some trees, like the Black Walnut, grow rapidly from their earliest youth. Others grow very slowly for the first few years. The stem of the Longleaf Pine, at 4 years old, is usually not more than 5 inches in length. During this time the roots have been growing instead of the stem. The period of its rapid growth in height comes later.

The place where a tree stands has a great influence on its rate of growth. Thus the trees on a hillside are often much smaller than those of equal age in the rich hollow below, and those on the upper slopes of a high mountain are commonly starved and stunted in comparison with the vigorous forest lower down. The Western Chinquapin, which reaches a height of 150 feet in the coast valleys of northern California, is a mere shrub at high elevations in the Sierra Nevada. The same thing is often observed in passing from the more temperate regions to the far north. Thus the Canoe Birch, at its northern limit, rises only a few inches above the ground, while farther south it becomes a tree sometimes 120 feet in height.

THE REPRODUCTIVE POWER OF TREES.

Another matter which is of the deepest interest to the forester is the reproductive power of his trees. Except in the case of sprouts and other growth fed by old roots, this depends first of all on the quantity of the seed which each tree bears; but so many other considerations affect the result that a tree which bears seed abundantly may not reproduce itself very well. A part of the seed is always unsound, and sometimes much the larger part, as in the case of the Tulip Tree. But even a great abundance of sound seed does not always insure good reproduction. The seeds may not find the right surroundings for successful germination, or the infant trees may perish for want of water, light, or suitable soil. Where there is a thick layer of dry leaves or needles on the ground, seedlings often perish in great numbers because their delicate rootlets can not reach the fertile soil beneath. The same thing happens when there is no humus at all and the surface is hard and dry. The weight of the seed also has a powerful influence on the character of reproduction. Trees with heavy seeds, like oaks, hickories, and chestnuts, can sow them only in their own neighborhood, except when they stand on steep hillsides or on the banks of streams, or when birds and squirrels carry the nuts and acorns to a distance. Trees with light, winged seeds (fig. 16), like the poplars, birches, and pines, have a great advantage over the others,

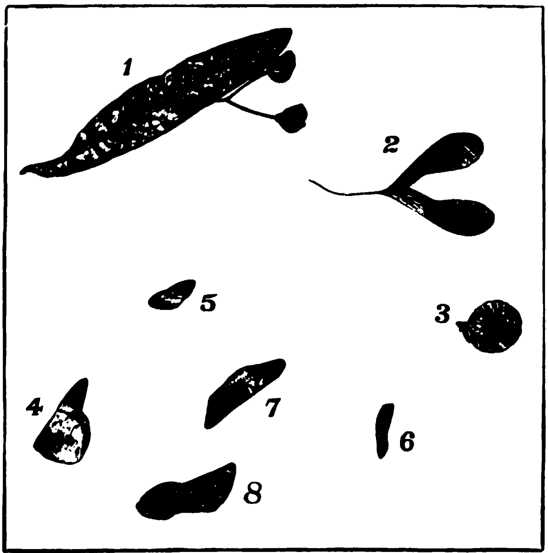

FIG. 16.—Winged seeds: 1, Basswood; 2, Boxelder; 3, Elm; 4, Fir; 5 to 8, Pine.

because they can drop their seeds a long way off. The wind is the means by which this is brought about, and the adaptation of the seeds themselves is often very curious and interesting. The wing of a pine seed, for example, is so placed that the seed whirls when it falls, in such a way that it falls very slowly. Thus the wind has time to carry it away before it can reach the ground. In heavy winds pine and other winged seeds are blown long distances—sometimes as much as several miles. This explains how certain kinds of trees, like the Gray Birch and the White Pine, grow up in the middle of open pastures, and how others, such as the Lodgepole Pine, cover great areas, far from the parent trees, with young growth of even age.

Such facts help to explain why, in certain places, it happens that when pines are cut down oaks succeed them, or when oaks are removed pines occupy the ground. It is very often true that young trees of one kind are already growing unnoticed beneath old trees of another, and so are ready to replace them whenever the old trees are cut away.

PURE AND MIXED FOREST.

The nature of the seed has much to do with the distribution of trees in pure or mixed forest. Some kinds of trees usually grow in bodies of some extent containing only a single kind; in other words, in pure forest. The Longleaf Pine of the South Atlantic and Gulf States is of this kind, and so is the Lodgepole Pine of the West. Conifers are more apt to grow in pure forest than broadleaf trees, because it is more common for them to have winged seeds. The greater part of the heavy-seeded trees in the United States are deciduous, and most of the deciduous trees grow in mixed forest, although there are some conspicuous exceptions. But even in mixed forests small groups of trees with heavy seeds are common, because the young trees naturally start up beneath and around the old ones. A heavy seed, dropping from the top of a tall tree, often strikes the lower branches in its fall and bounds far outside the circle of the crown. Trees which are found only, or most often, in pure forest are the social or gregarious kinds; those which grow in mixture with other trees are called scattered kinds. Most of the hardwood forests in the United States are mixed; and many mixed forests, like that in the Adirondacks, contain both broadleaf trees and conifers. The line between gregarious and scattered species is not always well marked, because it often happens that a tree may be gregarious in one place and live with many others elsewhere. The Western Yellow Pine, which forms, on the plateau of central Arizona, perhaps the largest pure pine forest of the earth, is frequently found growing with other species in the mountains, especially in the Sierra Nevada of central California.

Trees which occupy the ground to the exclusion of all others do so because they succeed better, under the conditions, than their competitors. It may be that they are able to get on with less water, or to grow on poorer soil, their rate of growth or power of reproduction

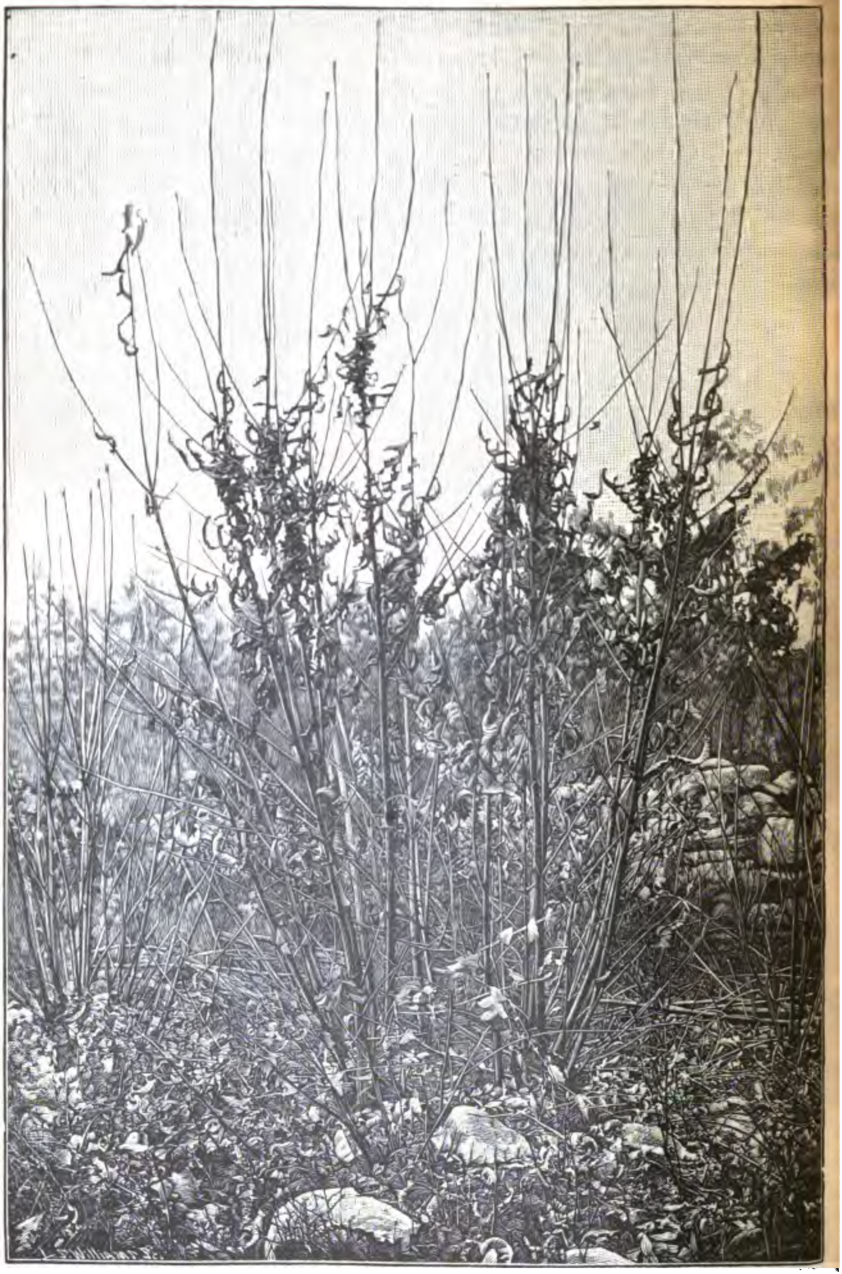

FIG. 17.—Chestnut sprouts from the stump.

may be greater, or there may be some other reason why they are better fitted for their surroundings. But the gregarious trees are not all alike in their ability to sustain themselves in different situations, while the differences between some of the mixed-forest species are very marked indeed. Thus, Black Walnut, as a rule, grows only in rich, moist soil and Beech only in damp situations. Fire Cherry, on the other hand, is most common on lands which have been devastated by fire, and the Rock Oak is most often found on dry, barren ridges. The Tupelo or Black Gum and the Red Maple both grow best in swamps, but it is a common thing to find them also on dry, stony soils at a distance from water. The knowledge of such qualities as these is of great importance in the management of forest lands.

REPRODUCTION BY SPROUTS.

Besides reproduction from seed, which plays so large a part in the struggle for the ground, reproduction by sprouts from old roots or stumps (fig. 17) is of great importance in forestry. Trees differ very much in their power of sprouting. In nearly all conifers except the California coast Redwood, which has this ability beyond almost every other tree, it is lacking altogether. The Pitch or Jack Pine of the Eastern United States has it also to some extent, but in most places the sprouts usually die in early youth and seldom make merchantable trees. In the broadleaf kinds, on the other hand, it is a general and very valuable quality. Young stumps, as a rule, are much more productive than old ones, although some prolific species, like the Chestnut, sprout plentifully in old age. Other species, like the Beech, furnish numerous sprouts from young stumps and very few or none at all from old ones, and still others never sprout freely even in early youth.

THE LIFE OF A FOREST.

The history of the life of a forest is a story of the help and harm which the trees receive from one another. On one side every tree is engaged in a relentless struggle against its neighbors for light, water, and food, the three things trees need most. On the other side, each tree is constantly working with all its neighbors, even those which stand at some distance, to bring about the best condition of the soil and air for the growth and fighting power of every other tree.

A COMMUNITY OF TREES.

The life of a community of trees is an exceedingly interesting one. A forest tree is in many ways as much dependent upon its neighbors for safety and food as are the inhabitants of a town upon one another. The difference is that in a town each citizen has a special calling or occupation in which he works for the service of the commonwealth, while in the forest every tree contributes to the general welfare in nearly all the ways in which it is benefited by the community. A forest tree helps to protect its neighbors against the wind, which might overthrow them, and the sun, which is ready to dry up the soil about their roots or to make sun cracks in their bark by shining too hotly upon it (fig. 18). It enriches the earth in which they stand by the fall of its leaves and twigs, and aids in keeping the air about their crowns, and the soil about their roots, cooler in summer and warmer in winter than it would be if each tree stood alone. With the others it forms a common canopy under which the seedlings of all the members of this protective union are sheltered in early youth, and through which the beneficent influence of the forest is preserved and extended far beyond the spread of the trees themselves. But while this fruitful cooperation exists, there is also present, just as in a village or a city, a vigorous strife for the good things of life. For a tree the best of these, and often the hardest to get, are water for the roots and space and light for the crown. In all but very dry places there is water enough for

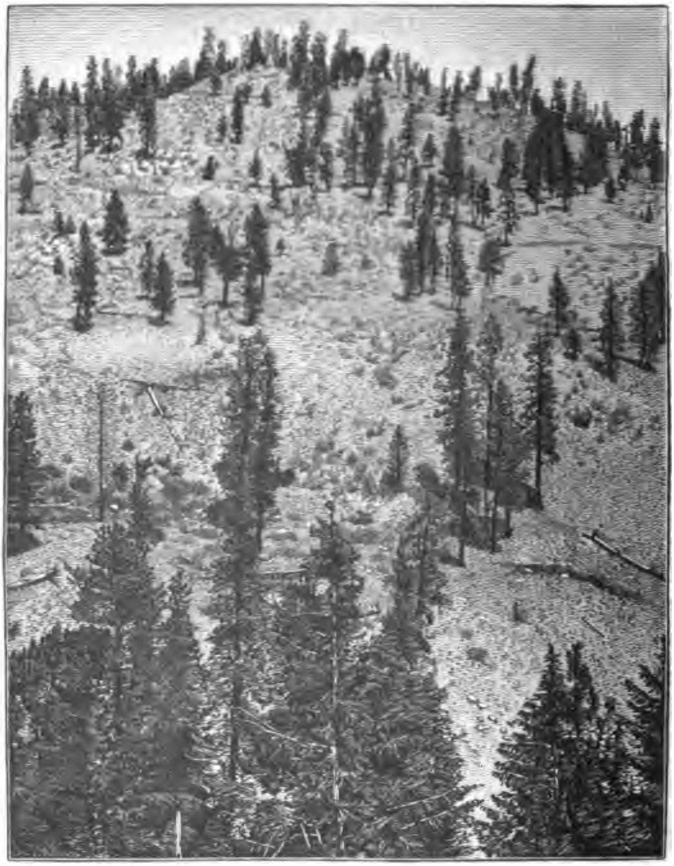

FIG. 18.—Forest trees standing too far apart to help each other. Lake Chelan, Washington.

all the trees, and often more than enough, as for example in the Adirondack forest. The struggle for space and light is thus more important than the struggle for water, and as it takes place above ground it is also much more easily observed and studied.

Light and space are of such importance because, as we have seen, the leaves can not assimilate or digest food except in the presence of light and air. The rate at which a tree can grow and make new wood is decided chiefly by its ability to assimilate and digest plant food. This power depends upon the number, size, and health of the leaves, and these in turn upon the amount of space and light which the tree can secure.

THE LIFE OF A FOREST CROP.

The story of the life of a forest crop is then largely an account of the competition of the trees for light and room, and, although the very strength which enables them to carry on the fight is a result of their association, still the deadly struggle, in which the victims are many times more in number than those which survive, is apt alone to absorb the attention. Yet the mutual help of the trees to each other is always going quietly on. Every tree continually comforts and assists the other trees, which are its friendly enemies.

The purpose here is to follow the progress of a forest crop of uniform age from the seed through all the successive phases of its life until it reaches maturity, bears seed in its turn, and finally declines in fertility and strength until at last it passes away and its place is filled by a new generation. The life history which we are about to follow, as it unfolds itself through the course of several hundred years, is full of struggle

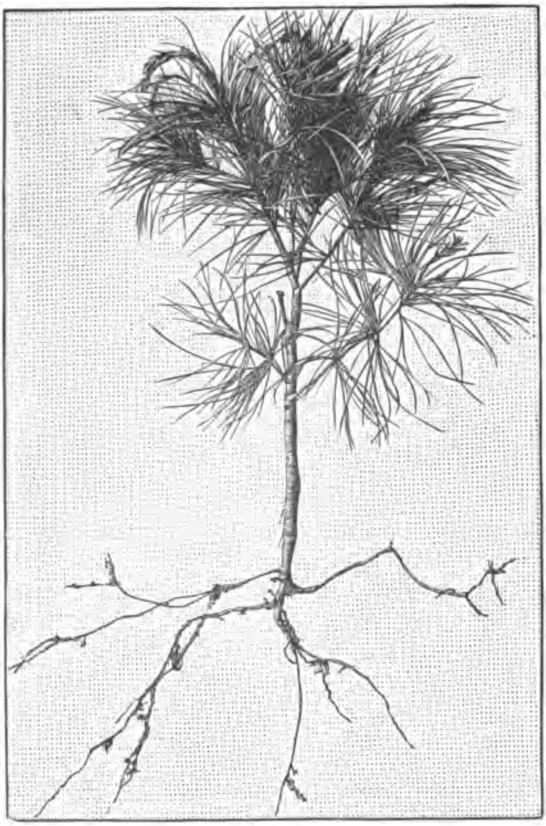

FIG. 19.—A White Pine seedling, showing the slender roots.

and danger in youth, restful and dignified in age. The changes which pass over it are vast and full of the deepest interest, but they are very gradual. From beginning to end one stage melts insensibly into the next. Still, in order to study and describe them conveniently, each stage must have limits and a name.

THE SEVEN AGES OF A TREE.

A very practical way of classifying trees according to size is the following: Young trees which have not yet reached a height of 3 feet are *seedlings* (fig. 19). They are called seedlings in spite of the fact that any tree, of whatever age, if it grew from a seed, is properly called a seedling tree. Trees from 3 to 10 feet in height are *small saplings*, and from 10 feet in height until they reach a diameter of 4 inches they are *large saplings*. *Small poles* are from 4 to 8 inches in diameter, and *large poles* from 8 to 12 inches in diameter. Trees from 1 to 2 feet through are *standards*, and, finally, all trees over 2 feet in diameter are *veterans*.

It is very important to remember that all these diameters are measured at the height of a man's chest, about 4 feet 6 inches from the ground. In forestry this is, roughly speaking, the general custom.

HOW THE CROP BEGINS.

Let us imagine an abundant crop of tree seeds lying on the ground in the forest. How they came there does not interest us at present; we do not care to know whether they were carried by the wind, as often happens with the winged seeds of many trees, such as pines and maples, whether the squirrels and birds dropped and planted some of them, as they frequently do acorns and chestnuts, or whether the old trees stood closely about and sowed the seeds themselves. We will suppose them to be all of one kind, and to be scattered in a place where the soil, the moisture, and the light are all just as they should be for their successful germination, and afterwards for the later stages of their lives. Even under the best conditions a considerable part of the fallen seed may never germinate, but in this case we will assume that half of it succeeds.

As each seed of our forest germinates and pushes its first slender rootlet downward into the earth, it has a very uncertain hold on life. Even for some time afterwards the danger from frost, dryness, and excessive moisture is very serious indeed, and there are many other foes by which the young seedlings may be overcome. It sometimes happens that great numbers of them perish in their earliest youth because their roots can not reach the soil through the thick, dry coating of dead leaves which covers it. But our young trees pass through the beginning of these dangers with comparatively little loss, and a plentiful crop of seedlings occupies the ground. As yet, however, each tle tree stands free from those about it. As yet, too, the life of the ung forest may be threatened or even destroyed by any one of the emies already mentioned, or it may suffer just as severely if the ver of the older trees above it is too dense. In the beginning of eir lives seedlings often require to be protected by the shade of their ders, but if this protection is too long continued they suffer for want light, and are either killed outright or live only to drag on stunted d unhealthy lives.

THE FOREST COVER ESTABLISHED.

The crop which we are following has had a suitable proportion of ade and light during its earliest years, and the seedlings have spread til their crowns begin to meet. Hitherto each little tree has had all e space in the air and soil that it needed for the expansion of its top d roots. This would have been entirely good, except that meanwhile e soil about the trees has been more or less exposed to the sun and ind, and so has become dryer and less fertile than if it had been under ver, and consequently the growth has been slow. But now that the rowns are meeting, the situation becomes wonderfully changed. he soil begins to improve rapidly, because it is protected by the cover f the meeting crowns (fig. 20) and enriched by the leaves and twigs hich fall from them.

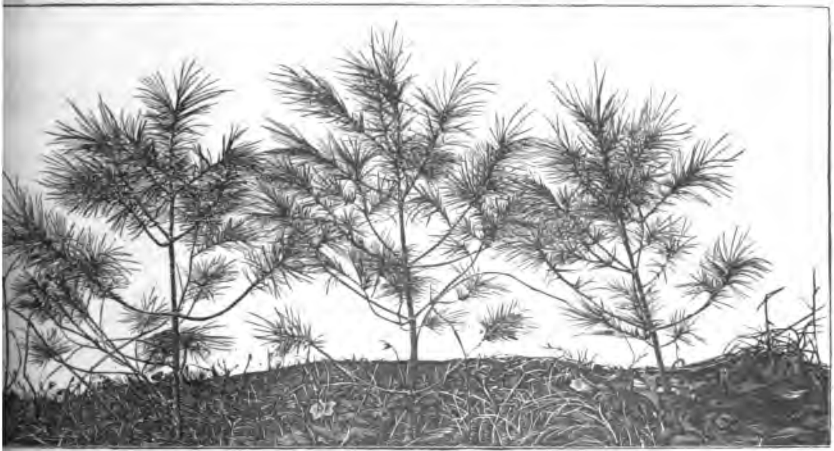

FIG. 20.—Young White Pine seedlings whose lower branches have just begun to interfere.

THE BEGINNING OF THE STRUGGLE.

In so far the conditions of life are better, and in consequence the rowth, and more especially the height growth, begins to show a arked increase. On the other hand, all the new strength is in immediate demand. With the added vigor which the trees are no helping each other to attain, comes the most urgent need for rapi development for the decisive struggle at hand. The roots of th young trees contend with each other in the soil for moisture and th plant food which it contains, while in the air the crowns struggle fo space and light. The latter is by far the more important battle. Th victors in it overcome by greater rapidity of growth at the ends of th branches, for it is by growth there, and there only, that trees increas in height and spread of crown. Growth in this way was going o unchecked among the young trees before the crowns met, but now onl the upward-growing branches can develop freely. The leaves at th ends of the side branches have now less room and, above all, less ligh for they are crowded and thrust aside by those of the other tree Very often they are bruised by thrashing against their neighbors whe the wind blows, or even broken off while still in the bud. Leave exposed to such dangers are unhealthy. They transpire less than th healthy undisturbed leaves of the upper part of the crown, and mo and more of the undigested food from the roots goes to the strong leaves at the top as the assimilating power of the side leaves dwindl with the loss of light. The young branches share the fortunes of the leaves and are vigorous or sickly according to the condition of the latte For this reason the growth of the tops increases, while that of the low lateral branches, as the tops cover them with a deeper and deep shade, becomes less and less. Gradually it ceases altogether, and th branches perish. This process is called natural pruning, and fro the time when it begins the existence of the young forest, unless should be overtaken by fire or some other great calamity, is practicall secure.

GROWTH IN HEIGHT.

At this time, as we have seen, the crowns of all the young trees are growing faster at the tops than at the sides, for there is unlimited room above. But some are growing faster than others, either because their roots are more developed or in better soil than those of the trees about them, because they have been freer from the attacks of insects and other enemies, or for some similar reasons. Some trees have an inborn tendency to grow faster than others of the same species in the same surroundings, just as one son in a family is often taller than the brothers with whom he was brought up.

Rapid growth in height, from whatever cause it proceeds, brings not only additional light and air to the tree which excels in it, but also the chance to spread laterally, and so to complete the defeat of its slower rivals by overtopping them.

THE STRUGGLE CONTINUED.

Those trees which have gained this advantage over their neighbors e called dominant trees, while the surviving laggards in the race are id to be overtopped when they are hopelessly behind, and retarded hen less badly beaten. Enormous numbers of seedlings and small plings are suppressed and killed during the early youth of the rest. In the young crop which we are following many thousands rish upon every acre. Even the dominant trees, which are temrarily free when they rise above their neighbors, speedily come to conflict with each other as they spread, and in the end the greater rtion is overcome. It is a very deadly struggle, but year by year e differences between the trees become less marked. Each separate dividual clings to life with greater tenacity, the strife is more proacted and severe, and the number of trees which perish grows pidly smaller. But so great is the pressure when dense groups young trees are evenly matched in size and rate of growth that it not very unusual to find the progress of the young forest in its rly stages almost stopped and the trees uniformly sickly and underzed, on account of the crowding.

The forest we have been following has now passed through the nall-sapling stage, and is composed chiefly, but not exclusively, of rge saplings. Among the overtopped and retarded trees, which ften remain in size classes which the dominant trees have long since tgrown, there are still many low saplings. Even between the ominant trees, in a healthy forest, there are always great differences. crease in height is now going on rapidly among these high sapngs, and either in this stage or the next a point is reached when e topmost branches make their longest yearly growth, which is one ay of saying that the trees make their most rapid height growth as rge saplings or small poles. Later on, as we shall see, these upper ranches lengthen much more slowly, until, in standards and veterans, e growth in height is small, and in very old trees finally ceases together.

NATURAL PRUNING.

While the trees are pushing up most rapidly, the side branches are ost quickly overshaded, and the process of natural pruning goes on ith the greatest vigor. Natural pruning is the reason why old trees a dense forest have only a small crown high in the air, and why eir tall, straight trunks are clear of branches to such a height above e ground. The trunks of trees grown in the open, where even the wer limbs have abundance of light, are branched either quite to the round or to within a short distance of it (fig. 21). But in the forest ot only are the lower side branches continually dying for want of ght, but the tree rids itself of them after they are dead and so frees its trunk from them entirely. When a branch dies the annual laye of new wood is no longer deposited upon it. Consequently the dea

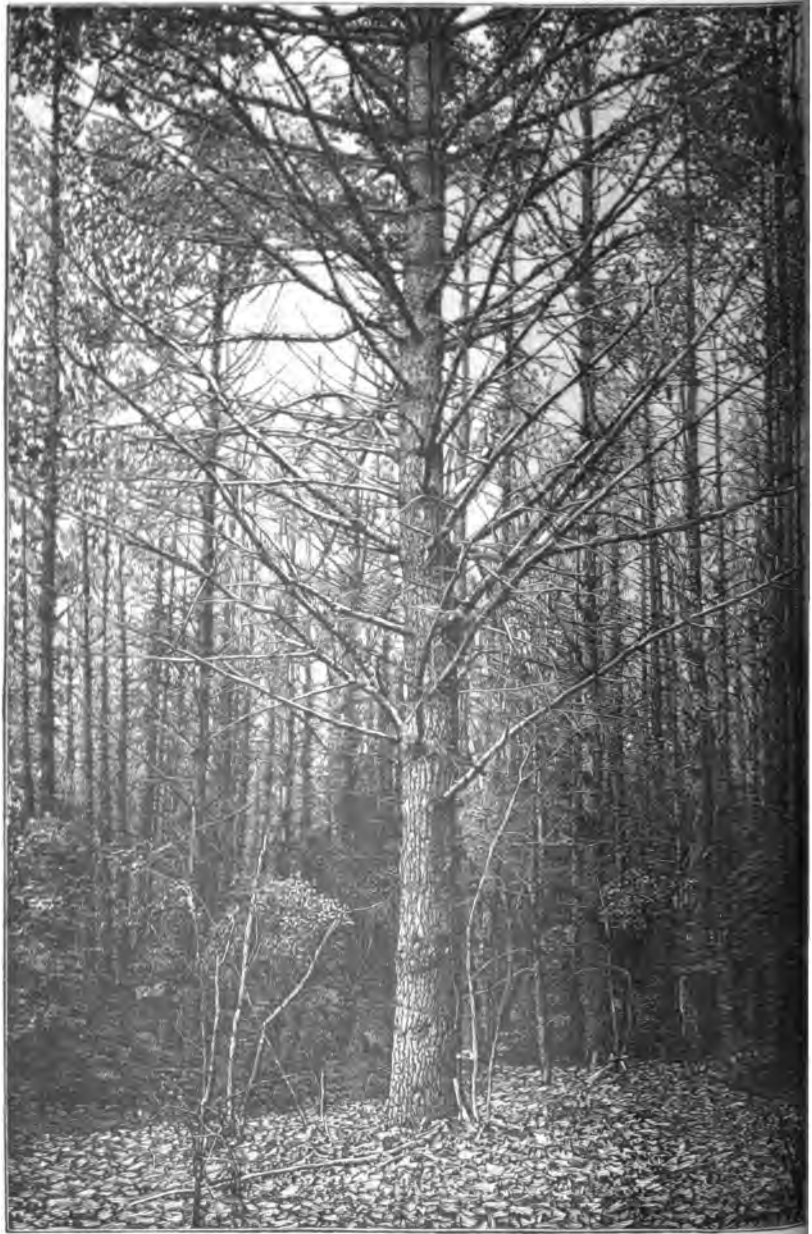

FIG. 21.—Imperfect natural pruning of a White Pine that stood too much alone in early youth. Milford, Pa.

branch, where it is inserted in the tree, makes a little hole in the fir coat of living tissue formed over the live wood after its death. Th dges of this hole make a sort of collar about the base of the dead ranch, and as a new layer is added each year they press it more and ore tightly. So strong does this compression of the living wood ome that at last what remains of the dead tissue has so little ngth that the branch is broken off by a storm or even falls of its weight. Then in a short time, if all goes well, the hole closes, after a while little or no exterior trace of it remains. Knots, as those which are found in boards, are the marks left in the k by branches which have disappeared.

THE CULMINATION OF GROWTH.

While the young trees are making clean trunks so rapidly during period of greatest yearly height growth they are also making their test annual gains in diameter, for these two forms of growth gen- lly culminate about the same time. A little later, if there is any erence, the young forest's highest yearly rate of growth in volume lso reached. For a time these three kinds of growth keep on at same rate as in the past, but afterwards all three begin to decrease. owth in diameter, and in volume also, if the trees are sound, goes ntil extreme old age, but height growth sinks very low while the others are still strong. For many years before this happens the ggle between the trees has not been so deadly, because they have almost without the means of overtopping one another. When end of the period of principal height growth is reached the trees interfering with each other very little, and the struggle for life ns again in a different way. As the principal height growth s, and the tops no longer shoot up rapidly above the side ches, the crowns lose their pointed shape and become compara- y flat. The chief reason why trees stop growing in height is that are not able to keep the upper parts of their crowns properly lied with water above a certain distance from the ground. This nce varies in different kinds of trees, and with the health and of the tree in each species, but there is a limit in every case which the water does not reach. The power of the pumping inery, more than any other quality, determines the height of the

THE END OF THE STRUGGLE.

w that the tree can no longer expand at the top, it must either r a great loss in the number of its leaves or be able to spread at sides; for it is clear that not nearly so many leaves can be exposed the light in the flattened crown as in the pointed one, just as a ointed roof has more surface than a flat one (fig. 22). It is just at is time, too, that the trees begin to bear seed most abundantly, and is of the greatest importance to each tree that its digestive apparatus in the leaves should be able to furnish a large supply of digested food. Consequently the struggle for space is fiercely renewed, only now the trees no longer attempt to overtop one another, having lost the power, but to crowd one another away at the sides. The whole forest might suffer severely at this point from a deadlock such as sometimes happens in early youth were it not for the fact that the trees, as they grow older, become more and more sensitive to any shade. Many species which stand crowding fairly well in youth can not thrive in age unless their crowns are completely free on every side. Each of the victors in this last phase of the struggle is the survivor of hundreds (or sometimes even of thousands) of seedlings. Among very numerous competitors they have shown themselves to be the best adapted to their surroundings.

Natural selection has made it clear that these are the best trees for the place. These are also the trees which bear the seed whence the younger generations spring. Their offspring will inherit their fitness to a greater or less degree, and in their turn will be subjected to the sa rigorous test, by which only the best are allow to reach maturity. Under this sifting out of weak and the unfit, our native trees have b prepared through thousands of generations to meet the conditions under which they must live. This is why they are so much more apt to succ than species from abroad, which have not b fitted for our climate and soil by natural selectio

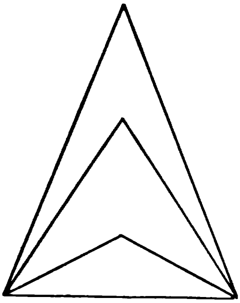

FIG. 22.—Diagram to show why a sharply conical crown receives more light than a flat one.

The forest which we saw first in the seed h now passed through all the more vigorous a active stages of its life. The trees have beco standards and veterans, and large enough to be valuable for lum Rapid growth in height has long been at an end, diameter growt slow, and the forest as a whole is increasing very little in volume as time goes on. The trees are ripe for the harvest.

Out of the many things which might happen to our mature forest, we will only consider three.

DEATH FROM WEAKNESS AND DECAY.

In the first place, we will suppose that it stands untouched until, lik the trees of the virgin forest, it meets its death from weakness an decay.

The trees of the mature primeval forest live on, if no acciden intervene, almost at peace among themselves. At length all confli between them ends. The whole power of each tree is strained in new struggle against death, until at last it fails. One by one the o disappear. But long before they go the forerunners of a ne generation have sprung up wherever light came in between their solated crowns. As the old trees fall, with intervals often of many years between their deaths, young growth of various ages rises to take heir place (fig. 23), and when the last of the old forest crop has vanished here may be differences of a hundred years among the young trees which succeed it. An even-aged crop of considerable extent, such as we have been considering, is not usual in the virgin forest, where trees of very different ages grow side by side, and when it does occur he next generation is far less uniform. The forest whose history has ust been sketched was chosen, not because it represents the most ommon type of natural forest, but because it illustrates better than ny other the progress of forest growth.

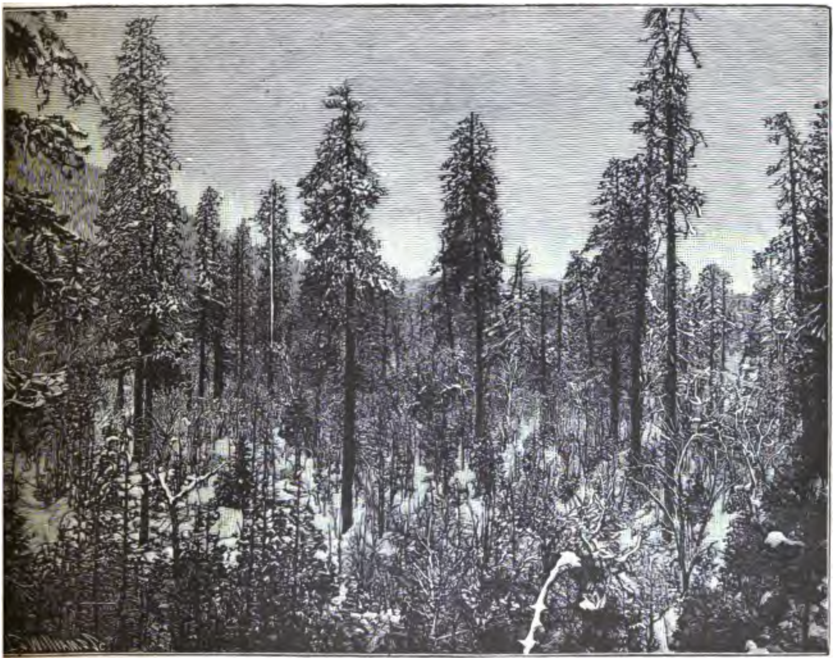

FIG. 23.—Young growth under old trees. Southwestern Oregon.

The wood of a tree which dies in the forest is almost wholly wasted. For a time the rotting trunk may serve to retain moisture, but there s little use for the carbon, oxygen, and hydrogen which make up its reater part. The mineral constituents alone form a useful fertilizer, ut most often there is already an abundance of similar material in he soil. Not only is the old tree lost, but ever since its maturity it as done little more than intercept, to no good purpose, the light which would otherwise have given vitality to a valuable crop of ounger trees. It is only when the ripe wood is harvested properly nd in time that the forest attains its highest usefulness.

nearly all the ways in which it is benefited by the community. A forest tree helps to protect its neighbors against the wind, which might overthrow them, and the sun, which is ready to dry up the soil about their roots or to make sun cracks in their bark by shining too hotly upon it (fig. 18). It enriches the earth in which they stand by the fall of its leaves and twigs, and aids in keeping the air about their crowns, and the soil about their roots, cooler in summer and warmer in winter than it would be if each tree stood alone. With the others it forms a common canopy under which the seedlings of all the members of this protective union are sheltered in early youth, and through which the beneficent influence of the forest is preserved and extended far beyond the spread of the trees themselves. But while this fruitful cooperation exists, there is also present, just as in a village or a city, a vigorous strife for the good things of life. For a tree the best of these, and often the hardest to get, are water for the roots and space and light for the crown. In all but very dry places there is water enough for

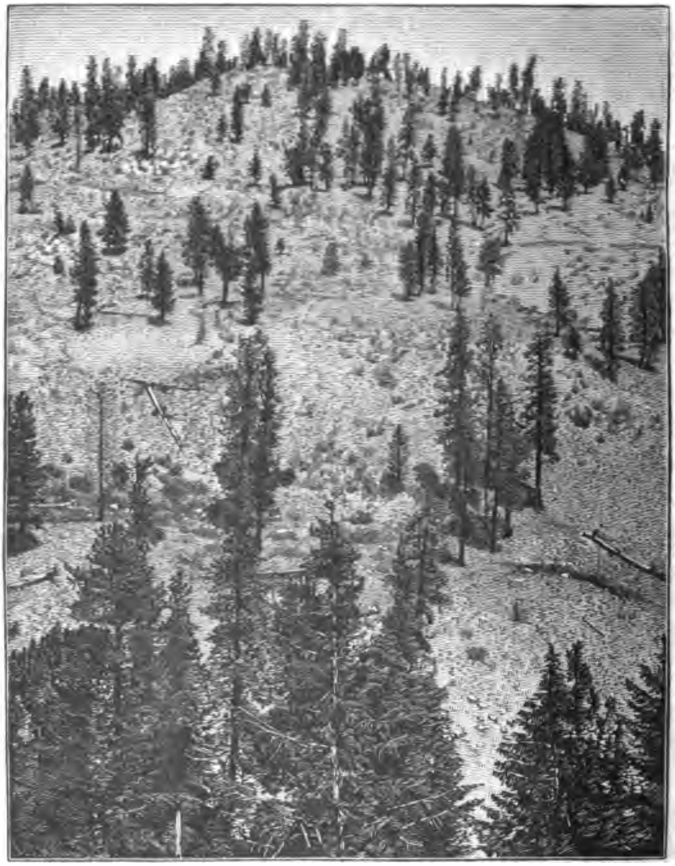

FIG. 18.—Forest trees standing too far apart to help each other. Lake Chelan, Washington.

all the trees, and often more than enough, as for example in the Adirondack forest. The struggle for space and light is thus more important than the struggle for water, and as it takes place above ground it is also much more easily observed and studied.

Light and space are of such importance because, as we have seen, the leaves can not assimilate or digest food except in the presence of light and air. The rate at which a tree can grow and make new wood is decided chiefly by its ability to assimilate and digest plant food. This power depends upon the number, size, and health of the leaves, and these in turn upon the amount of space and light which the tree can secure.

THE LIFE OF A FOREST CROP.

The story of the life of a forest crop is then largely an account of the competition of the trees for light and room, and, although the very strength which enables them to carry on the fight is a result of their association, still the deadly struggle, in which the victims are many times more in number than those which survive, is apt alone to absorb the attention. Yet the mutual help of the trees to each other is always going quietly on. Every tree continually comforts and assists the other trees, which are its friendly enemies.

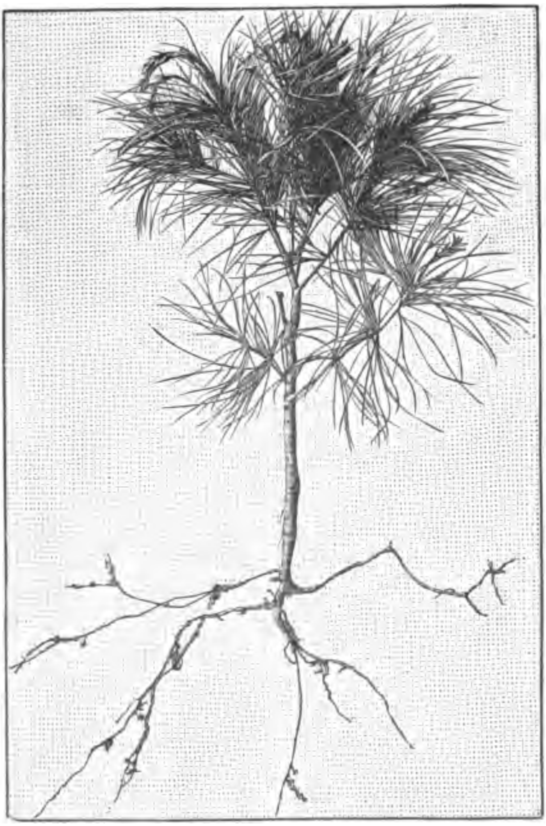

FIG. 19.—A White Pine seedling, showing the slender roots.

The purpose here is to follow the progress of a forest crop of uniform age from the seed through all the successive phases of its life until it reaches maturity, bears seed in its turn, and finally declines in fertility and strength until at last it passes away and its place is filled by a new generation. The life history which we are about to follow, as it unfolds itself through the course of several hundred years, is full of struggle to suffer from trampling than from being eaten, or broadleaf tree and so more likely to be devoured, they should be protected fro pasturing animals until they are large enough to be out of danger.

GRAZING AND FIRE.

Grazing in the forest does harm in three ways. First, it is a ferti cause of forest fires. Burning the soil cover of grass and othe plants improves the grazing, either permanently, by destroying th forest and so extending the area of pasturage, or temporarily, b

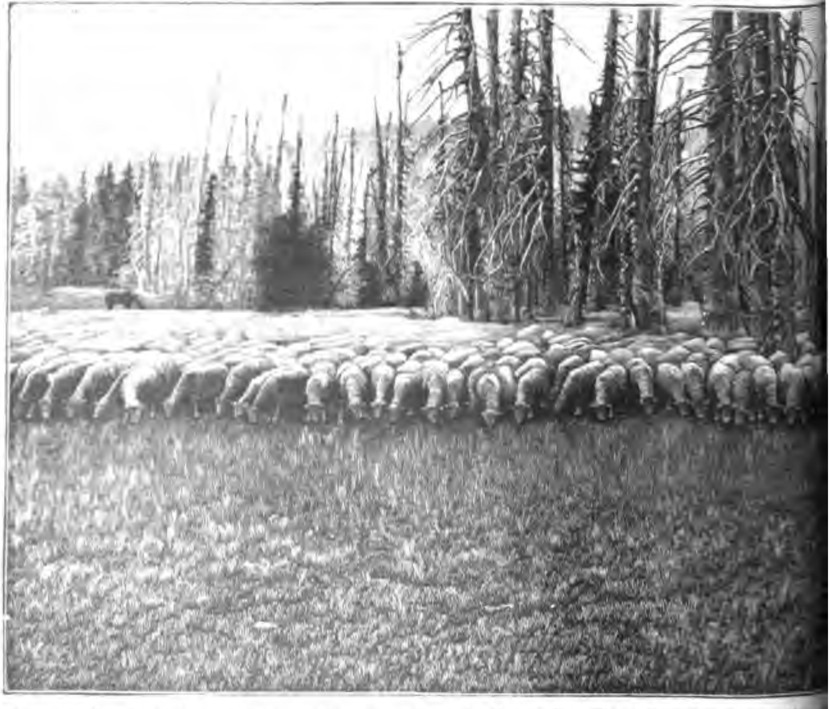

Fig. 26.—Band of sheep in a forest reserve. Cascade Mountains, Waco County, Oreg. Alt 7,500 feet.

improving the quality of the feed. For one or the other of th objects, but chiefly for the latter, vast areas are annually burned ov in nearly every part of the United States where trees grow. T great majority of these fires do not kill the old trees, but the ha they do the forest and, eventually, the forage plants themselves very serious indeed. The sheepmen of the West are commo accused of setting many forest fires to improve the grazing, and th are also vigorously defended from this charge. But the fact rem that large areas where sheep now graze would be covered with for ot for the action of more or less recent fires.

TRAMPLING.

Trampling is the second way in which grazing animals injure the orest. Cattle and horses do comparatively little harm, although heir hoofs compact the soil and often tear loose the slender rootlets f small trees. Sheep, on the contrary, are exceedingly harmful ig. 25), especially on steep slopes and where the soil is loose. In uch places their small, sharp hoofs cut and powder the soil, break nd overthrow the young trees, and often destroy promising young orests altogether. In many places the effect of the trampling is to estroy the forest floor and to interfere very seriously with the flow f streams. In the Alps of southern France sheep grazing led to the estruction, first, of the mountain forests, and then of the grass which d replaced them, and thus left the soil fully exposed to the rain. reat floods followed, beds of barren stones were spread over the rtile fields by the force of the water, and many rich valleys were most or altogether depopulated. Besides the loss occasioned in this y, it has cost the French people tens of millions of dollars to repair damage begun by the sheep, and the task is not yet finished. The s to the nation is enormously greater than any gain from the moun- n pastures could have been, and even the sheep owners themselves, r whose profit the damage was done, were losers in the end, for ir industry in that region was utterly destroyed.

BROWSING.

he third way in which grazing animals injure the forest is by feed- on the young trees. In the western part of the United States, ere most of the forests are evergreen, this is far less important n the damage from either fire or trampling, for sheep and other mals seldom eat young conifers if they can get other food. en where broadleaf trees prevail browsing rarely leads to the truction of any forest, although it commonly results in scanty oung growth, often maimed and unsound as well. Goats are espe- ially harmful, and where they abound the healthy reproduction of roadleaf trees is practically impossible. In the United States they re fortunately not common. Cattle devour tender young shoots nd branches in vast quantities, often living for months on little else, nd sheep are destructive in the same way. Hogs also find a living n the forest, but they are less harmful, because a large part of their ood consists of seeds and nuts. East of the Great Plains very large umbers of cattle and hogs are turned into the woods, but sheep razing in the forest is most widely developed in the West, and espe- ially in California, where it should be prevented altogether, in Ore- on and Washington, where it should be regulated and restricted, and n some interior regions, like Wyoming and New Mexico, where it should be rigidly excluded from all steep mountain regions, and carefully regulated on more level ground.

FOREST INSECTS.

Insects are constantly injuring the forest, just as year by year they bring loss to the farm. Occasionally their ravages attain enormous proportions. Thus a worm, which afterwards develops into a sawfly, has since 1882 killed nearly every full-grown larch in the Adirondacks by eating away the leaves. Even the small and vigorous larches do not escape altogether from these attacks. Conifers, such as the larch and spruce, are much more likely to suffer from the attacks of insects than broadleaf trees. About the year 1876 small bark beetles began to kill the mature spruce trees in the Adirondacks, and ten years later, when the worst of the attack was past, the forest had been practically deprived of all its largest spruces. This pest is still at work in northern New Hampshire and in Maine.

FOREST FUNGI.

Fungi attack the forest in many ways. Some kill the roots of trees, some grow upward from the ground into the trees and change the sound wood of the trunks to a useless rotten mass, and the minute spores (or seeds) of others float through the air and come in co[illegible] with every external part of the tree above ground. Wherever wood is exposed there is danger that spores will find lodgment [illegible] breed disease. This is a strong reason why all wounds, such as [illegible] made in pruning, should be covered with some substance like pai[illegible] tar to exclude the air and the spores it carries.

WIND IN THE FOREST.

The effect of wind in the virgin forest is not wholly inju[illegible] Although in many regions it overthrows great numbers of old [illegible] their removal is usually followed by a vigorous young growth [illegible] the old trees stood. In this way the wind helps to keep the [illegible] full of young and healthy trees. But it also breaks and blows [illegible] great numbers of useful growing members of the forest (fig. [illegible] Much of this windfall occurs among shallow-rooted trees, or w[illegible] the ground is soft because soaked with water, or where the trees hav[illegible] been weakened by unsoundness or fire. Some storms are stron[illegible] enough to break the trees they can not overthrow. Damage fro[illegible] wind is not uncommon in many parts of the United States, and [illegible] places the loss from it is very serious. Near the town of High Spring[illegible] in Alachua County, Fla., for example, in a region very subject [illegible] ms, there is a tract of many square miles, once covered wi[illegible]

Longleaf Pine, over which practically all the trees were killed by a great storm several years ago. Some were thrown flat, some were so racked and so broken in the top that they died, and very many were snapped off 15 to 30 feet above the ground. There is little use in taking precautions against such great calamities, yet the loss from windfall may be very much reduced by judicious cutting. An unbroken forest is least exposed.

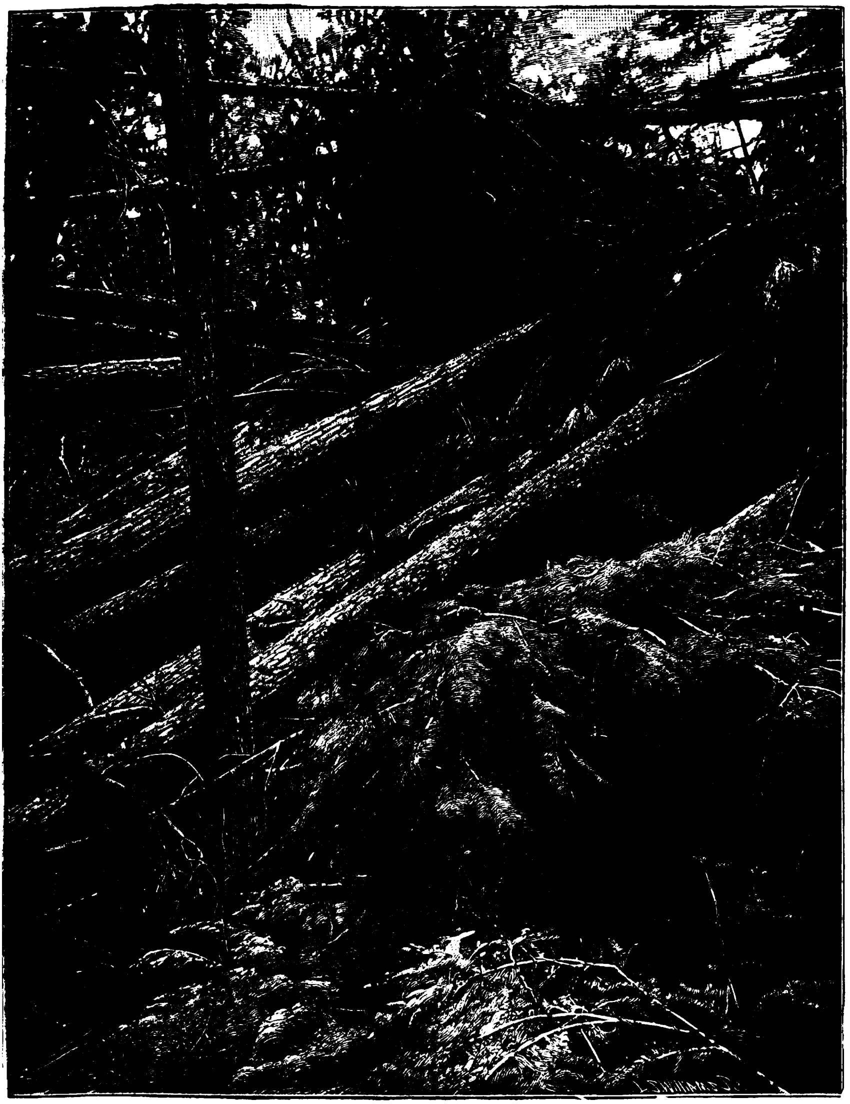

FIG. 26.—A windfall in the Olympic Forest Reserve, Washington.

SNOW IN THE FOREST.

Snow often loads down, breaks, and crushes tall young trees (fig. 27), especially if wet snow falls heavily before the broadleaf trees have shed their foliage in the fall. Such injury is difficult to guard against,

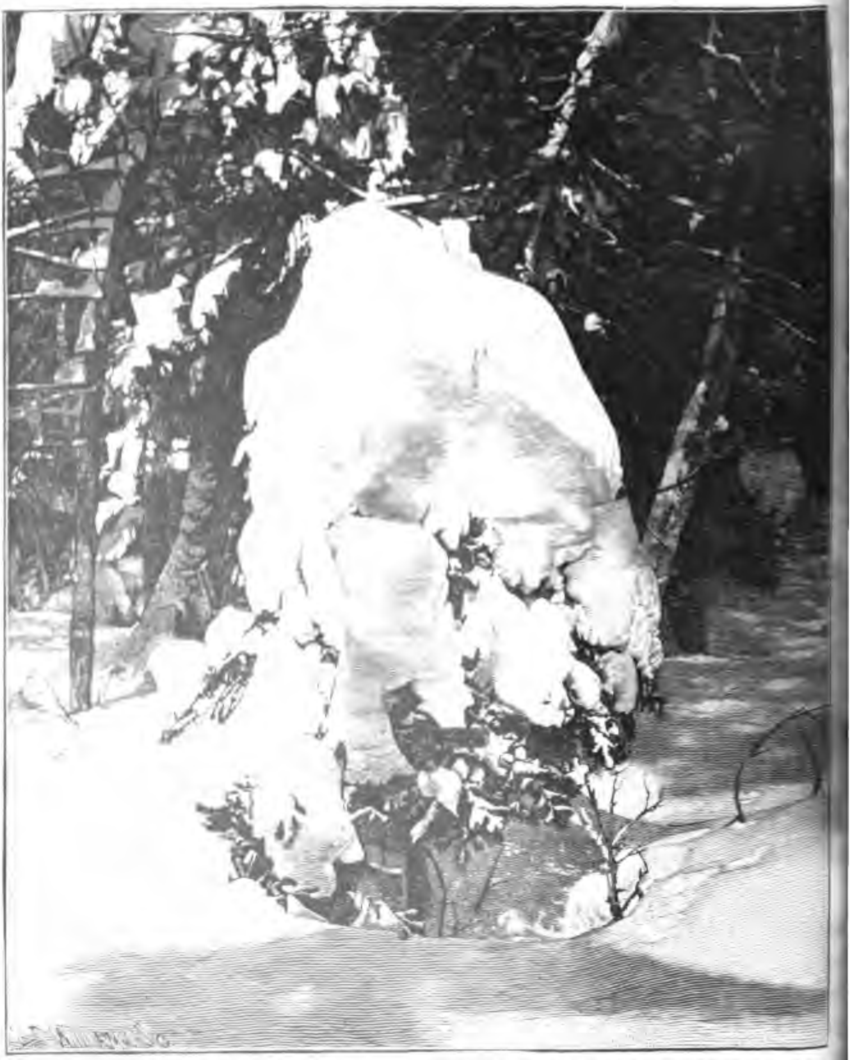

FIG. 27.—A young spruce loaded with snow. Avalanche Lake, Adirondack Mountains, New York.

but it is well to know that very slim, tall trees suffer more than those whose growth in diameter and height have kept better pace with each other. In many regions snow is so useful in protecting the soil and the young trees that the harm it does is quite overbalanced by its benefits.

FOREST FIRES.

Of all the foes which attack the woodlands of North America no her is so terrible as fire. Forest fires spring from many different uses. They are often kindled along railroads by sparks from the comotives. Carelessness is responsible for many fires. Settlers and rmers clearing land or burning grass and brush often allow the fire escape into the woods. Someone may drop a half-burned match or e glowing tobacco of a pipe or cigar, or a hunter or prospector may glect to extinguish his camp fire, or may build it where it will bur-w into the thick duff far beyond his reach, to smolder for days, or eeks, and perhaps to break out as a destructive fire long after he is one. Many fires are set for malice or revenge, and the forest is often urned over by huckleberry pickers to increase the next season's rowth of berries, or by the owners of cattle or sheep to make better asture for their herds.

g. 28.—The rotting stubs of fire-killed veterans of Red Fir surrounded by young standards of Red Fir and Western Hemlock. Olympic Forest Reserve, Washington.

Fire sometimes renews an old forest by killing the veterans and so ermitting vigorous young trees to take their place (fig. 25).

There is danger from forest fires in the dry portions of the spring nd summer, but those which do most harm usually occur in the fall. t whatever time of the year they appear, their destructive power epends very much on the wind. They can not travel against it except

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A PRIMER OF FORESTRY

SURFACE FIRES.

Surface fires (fig. 29) may be checked if they are feeble by beating them out with green branches or by raking the leaves away from a narrow strip across their course. The best tool for this purpose is a four-tined pitchfork or a common stable fork. In sandy regions a thin and narrow belt of sand is easily and quickly sprinkled over the ground with a shovel, and will check the spread of a weak fire, or even of a comparatively hot one if there is no wind. Dirt or sand thrown on a burning fire is one of the best of all means for putting it out.

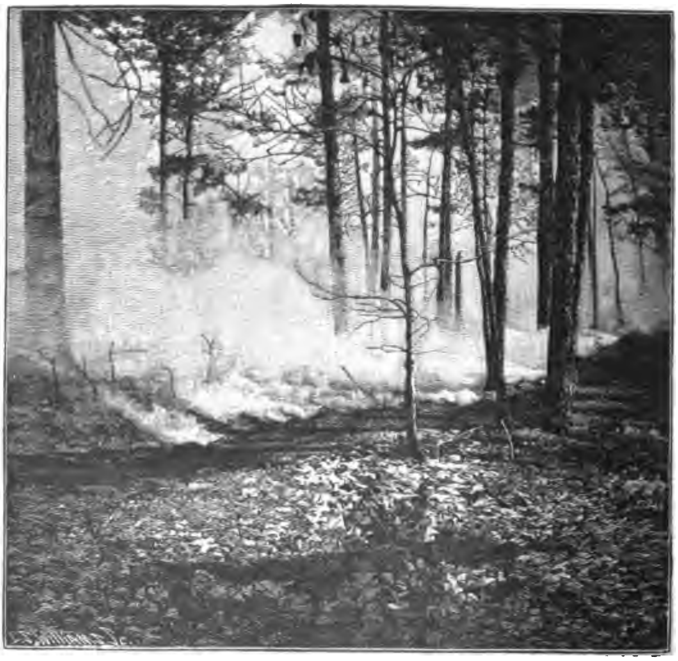

Fig. 29.—A surface fire burning slowly against the wind, southern New Jersey.

In dense forests with a heavy forest floor fires are often hot enough not only to kill the standing timber but to consume the trunks and branches altogether, and even to follow the roots far down into the ground. In forests of this kind fire spreads easily, creeping along on the surface or through the duff or under the bark of rotting fallen trees. In the same way it climbs dead standing trees and breaks out in bursts of flame high in the air. Dead trees help powerfully to spread a fire, for in high winds loose pieces of their burning bark are carried to almost incredible distances and drop into the dry forest far ahead, while in calm weather they scatter burning fragments all about them they fall. (See fig. 30.)

GROUND FIRES.

When the duff is very deep or the soil peaty a fire may burn beneath the surface of the ground for weeks or even months, sometimes showing its presence by a little smoke, sometimes without giving any sign of life. Even a heavy rain may fail to quench a fire of this kind, which often breaks out again long after it is believed to be entirely extinct. Fires which thus burn into the ground can sometimes be checked only by digging a trench through the layer of decaying wood and other vegetable matter to the mineral soil beneath. Ground fires usually burn much more slowly than surface fires, but they are exceptionally long lived and very hard to put out. It is of the first importance to attack such fires quickly before they have had time to burrow far beneath the surface of the ground. Surface fires are usually far

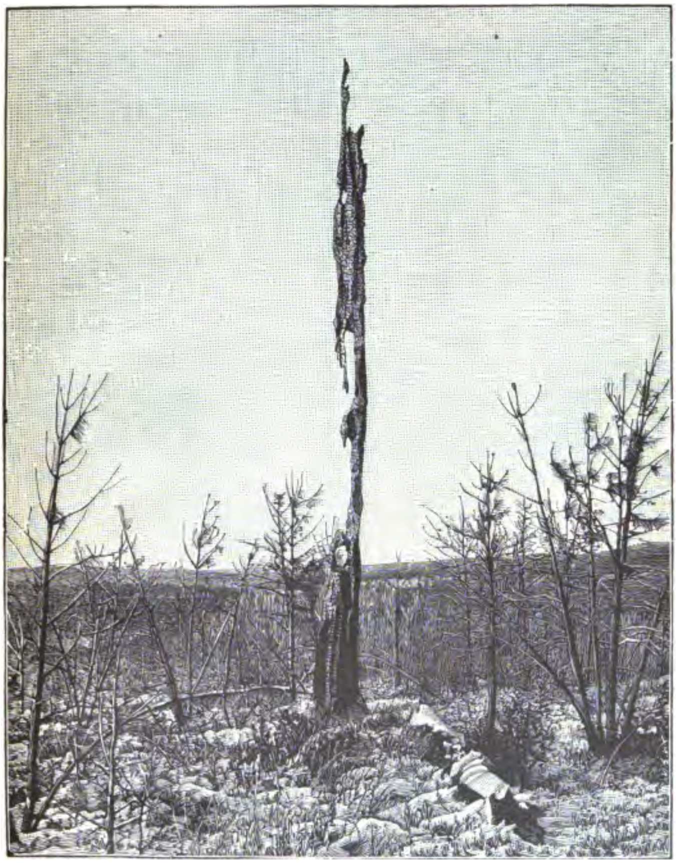

FIG. 30.—The effect of repeated fires. Not only the old trees are dead, but the seedlings which succeeded them have perished also. Western Yellow Pine in the Black Hills Forest Reserve, South Dakota.

less troublesome, but in either case fires which kill the trees are generally repeated again and again until the dead timber is consumed (fig. 31).

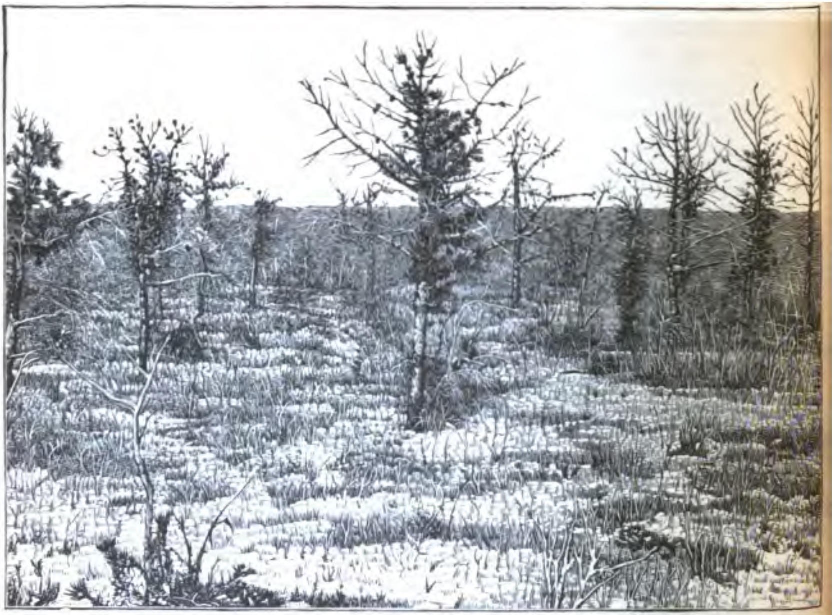

FIG. 31.—The result of recurring fires. The forest floor has disappeared and the pure white sand is left without covering. Southern New Jersey.

BACK FIRING.

The most dangerous and destructive forest fires are those which run both along the ground and in the tops of the trees. When a fire becomes intensely hot on the ground, it may run up the bark, especially if the trees are conifers, and burn in the crowns. Such fires are the fiercest and most destructive of all. Traveling sometimes faster than a man can run, they consume enormous quantities of valuable timber, burn fences, buildings, and domestic animals, and endanger or even destroy human lives. They can be checked only by rain or change of wind, or by meeting some barrier which they can not pass. A barrier of this kind is often made by starting another fire some distance ahead of the principal one. This back fire, as it is called, must be allowed to burn only against the wind d toward the main fire, so that when the two fires meet both must

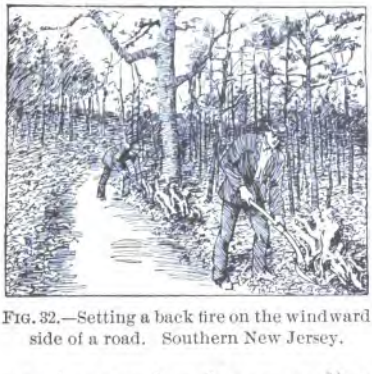

FIG. 32.—Setting a back fire on the windward side of a road. Southern New Jersey.

go out for lack of fuel. To prevent it from moving with the wind, a back fire should always be started on the windward side of a road (fig. 32) or a raked or sanded strip, or some other line which it can be kept from crossing. If it is allowed to escape it may become as dangerous as the main fire itself. Back fires are sometimes driven beyond control by a change of wind, but the chief danger from their use is caused by persons who, in excitement or fright, light them at the wrong time or n the wrong place. Still, there is no other means of fighting fires so powerful and none so effective when rightly used.

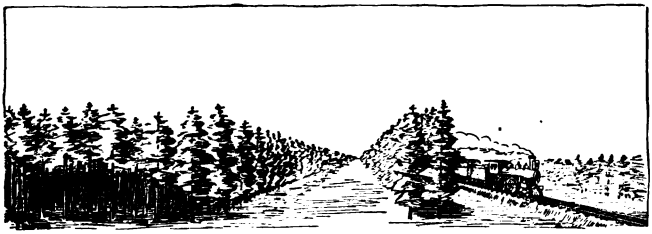

FIG. 33.—A fire line along a railroad with two cleared spaces separated by a double row of trees intended to catch the sparks.

FIRE LINES.

Fire lines—strips kept free from all inflammable material by burnng or otherwise—are very useful in checking small fires and of great value as lines of defense in fighting large ones. They are also very effective in keeping fires out of the woods, as, for example, along railroad tracks (fig. 33). But without men to do the fighting they are of as little use against really dangerous fires as forts without soldiers against invading armies.

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